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Age Structure and Growth Characteristics of the Endemic Fish *Oxygymnocypris stewartii* (Cypriniformes: Cyprinidae: Schizothoracinae) in the Yarlung Tsangpo River, Tibet

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Yin-Tao Jia and Yi-Feng Chen (2011) Age structure and growth characteristics of the endemic fish *Oxygymnocypris stewartii* (Cypriniformes: Cyprinidae: Schizothoracinae) in the Yarlung Tsangpo River, Tibet. *Zoological Studies* **50**(1): 69-75. The age structure and growth characteristics of *Oxygymnocypris stewartii* were studied using 430 specimens collected from the Yarlung Tsangpo River, Tibet. Our study on the length-frequency and age structure indicated that this population was suffering from unreasonable exploitation. The standard length (*SL*; mm)-body weight (*W*; g) relationship was $W = 1.30 \times 10^{-5} SL^{3.002}$. The *SL* ($L_t$)- and weight ($W_t$)-at-age relationships were described by von Bertalanffy growth functions as follows: $L_t = 877.4821[1 - e^{-0.1069 (t - 0.5728)}]$ and $W_t = 8805.1493[1 - e^{-0.1069 (t - 0.5728)}]^{2.997}$ for females, and $L_t = 599.3939[1 - e^{-0.1686(t - 0.6171)}]$ and $W_t = 3091.3496[1 - e^{-0.1686(t - 0.6171)}]^{3.098}$ for males. It was observed that *O. stewartii* grew faster during the 1st 3 yr than other schizothoracines inhabiting the same region, and then its growth became slower. Our study also indicated that (1) *O. stewartii*'s growth performance was relatively higher than those of other schizothoracines which inhabit the same region, and (2) its growth performance was relatively lower than those of other piscivore Cyprinidae fishes such as *Culter alburnus* Basilewsky which inhabit Wu and Cheng Lakes. Both of these characteristics might be related with its feeding habits and the environment in which it lives. Based on our results, we suggest that some regulations be promulgated as soon as possible. The government should publish a law to forbid fishermen from capturing *O. stewartii*. http://zoolstud.sinica.edu.tw/Journals/50.1/69.pdf

Key words: Cypriniformes, Age structure, Growth, Plateau fish.

Schizothoracines are the most abundant fishes which inhabit the Qinghai-Tibetan Plateau (Cao et al. 1981). They are characterized by restricted distributions, slow growth rates, low fecundity, and prolonged sexual maturity as adaptations to their rigorous environment (Wu and Wu 1992, Chen and Cao 2000). These life-history characteristics make them more vulnerable to intense exploitation (Buxton 1993).

The rich fishery resources in Tibet have not been fully exploited before, because of the local religion and traditional customs (Chen 2000). However, demands for fish and other aquatic products have recently rapidly increased due to enhanced immigration and gradual changes in many traditional customs. Moreover, booming local industry has also led to the immoderate exploitation of fish resources, which eventually resulted in sharp declines in abundances. Unfortunately, no regulations have been promulgated to reign in such exploitation.

Because the establishment of protective regulations for fish must be based on biological data of those fish (Bhatt et al. 2000), much

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research has been conducted to gain biological information on schizothoracines (Zhao et al. 1975, Yang et al. 2002, Chen et al. 2002a 2009, Li and Chen 2009). But few publications focused on *Oxygymnocypris stewartii*, an endemic fish to the Yarlung Tsangpo River system (Chen and Cao 2000) which has been listed as an endangered species in China's *Red Data Book of Endangered Animals* owing to its highly reduced population (Yue and Chen 1998). *Oxygymnocypris stewartii* occupies the top of the food chain in the Yarlung Tsangpo River, so decreases in its abundance might cause concomitant changes in the food chain. It was reported that when the top consumer in a food chain is reduced or removed, abundances might alternately increase and decrease at sequentially lower trophic levels, producing a "trophic cascade" (Wootton and Power 1993). Thorough knowledge of the age structure and growth parameters of *O. stewartii* would assist in attempts to conserve the species. The purposes of our study were to provide some information on the commercial fishing condition of *O. stewartii* and to conduct further research on its growth characteristics, which might provide some data for establishing corresponding laws and regulations for its conservation and also enrich the database of the study of plateau fish biology.

MATERIALS AND METHODS

Study area

The Yarlung Tsangpo River (82-97°E, 28-31° 15'N), the river with the highest elevation in the world, is the largest river in Tibet (Team of Chinese Academy of Science of the Scientific Expedition to the Qinghai-Xizang Plateau 1983). It originates from a glacier on the northern side of the middle Himalayas in Tibet, China, generally runs across the southern portion of the Qinghai-Tibetan Plateau from west to east, into India, where it is called the Brahmaputra River, and finally discharges its water into the Bay of Bengal. The river is 2057 km long with a drainage area more than 240 km^2 (Team of Chinese Academy of Science of the Scientific Expedition to the Qinghai-Xizang Plateau 1983).

Fish collection

In total, 430 specimens were sampled monthly from commercial catches during Apr. 2004-Sept. 2006 in the Yarlung Tsangpo River system (Fig. 1). The standard length (SL) (measured to the nearest 0.01 mm using dial calipers) and body weight (W) (measured to the nearest 0.1 g) of each fish were recorded. The sex was determined from the external appearance of the gonads. Because of the very thin and translucent gonads, it is difficult to confirm the presence of ovaries or testes by visual observation, and the sex of individuals that were < 2 yr old was not identified.

Age determination and age structure of *O. stewartii*

The annular characters were described, the periodicity of annular deposition was validated by Jia and Chen (2009), and the precision of readings of annuli among readers was also validated (Jia and Chen unpubl. data). Therefore, we used lapillus otoliths to determine the age of *O. stewartii* without repeating the validation process. Otoliths were prepared following Chen et al. (2002b) and Hsu and Tzeng (2009). An age was assigned by

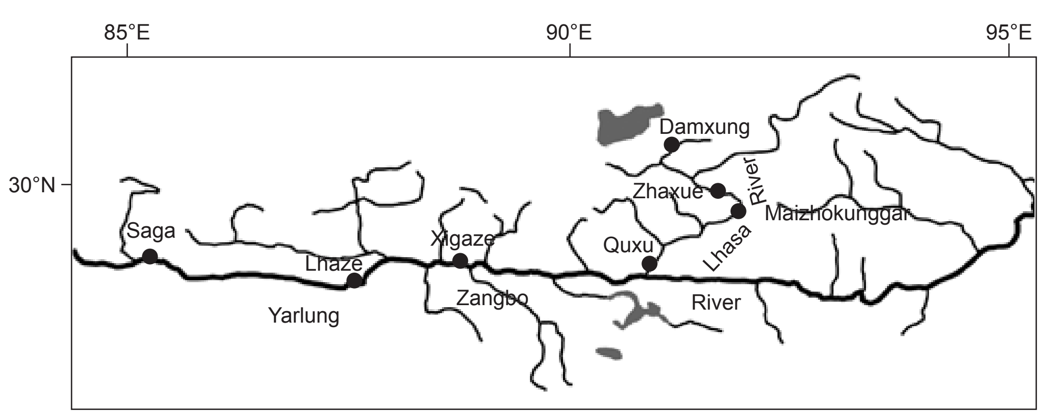

Fig. 1. Map of sampling locations.

counting the annuli; that is, if n annuli were read on the otolith, then that fish should belong to the age group $n + 1$ yr.

A percentage frequency table was prepared on the basis of the SL to record the ages of fish of different size groups, and to compute the age composition of *O. stewartii* (Yin 1995, Bhatt et al. 2000). Catches for which the age could be identified were used to prepare a frequency table, and all samples were used to further analyze the age structure.

Data analysis

The length-weight relationship was described by the exponential regression equation: $W = aSL^b$ where a is the intercept and b the slope. Variations (if any) in the length-weight relationships between males and females were analyzed through an analysis of covariance (ANCOVA).

The von Bertalanffy growth function (VBGF) (von Bertalanffy 1938) of the length-at-age was fitted to the data: $L_t = L_\infty(1 - \exp(-k(t - t_0)))$; where L_t is the predicted standard length at age t, and L_∞, k, and t_0 are the asymptotic length, growth constant (yr^{-1}), and theoretical age when the fish had 0 length. The following VBGF of the weight-at-age was used: $W_t = W_\infty(1 - \exp(-k(t - t_0)))^b$; where W_t is the predicted weight at age t, and W_∞ and b are the asymptotic length and slope, respectively, of the exponential regression of the length-weight relationship. Data for age were pooled to estimate the VBGF for each sex, and an analysis of the residual sum of squares (ARSS) was used to test the significance of the difference in the VBGF between the sexes (Chen et al. 1992). To validate the optimum function of the VBGF, 4 data groups which contained age 1 to 6 groups, age 1 to 7 groups, age 1 to 8 groups, and age 1 to 9 groups were respectively used to fit the function.

The growth performance index (φ) of the present population was estimated so that the growth parameters obtained in the present work and from reports by other authors in different geographical regions and populations could be compared. This index was calculated by the equation: $\varphi = \log_{10}k + 2\log_{10}L_\infty$ (Pauly and Munro 1984).

The instantaneous growth rate (G) (Yin 1995) was used to compare each year's growth rate with those of reports on other populations in Tibet (Yang et al. 2002, Chen et al. 2002a 2009, Li and Chen 2009). The instantaneous growth rate was calculated as:

$$G = (\ln W_2 - \ln W_1) / (t_2 - t_1);$$

where W_2 and W_1 are the mean weight in grams at ages t_2 and t_1, respectively, and t_2 and t_1 are the ages of the specimens.

The growth inflexion (t_i) was calculated by the equation: $t_i = \ln b/k + t_0$ (Yin 1995).

All statistical analyses were carried out using the software packages SPSS 13.0 (SPSS, Chicago, IL, USA) and Origin 8.0 (Microcal, USA).

RESULTS

Length frequency and the sex ratio

All specimens ranging 46.0-546.0 mm SL and 0.7-2502 g TW were analyzed (Fig. 2). The 200-400 mm TL size group accounted for 85.78% of the total sample. Identified females ranged in size from 117.0 to 546.0 mm SL and 538.9 to 2502.0 g body weight, while those of males were from 103.7 to 441.0 mm SL and 14.2 to 1006.0 g body weight (Table 1). The sex ratio (♂ : ♀) was 1: 2.02.

Age structure of *O. stewartii*

For all samples, 282 specimens were successfully aged, and the maximum ages observed were 20 yr for females (451 mm SL and 1028 g TW) and 9 yr for males (425 mm SL and 853 g TW). In total, 423 specimens (individuals the age of which exceed 11 yr were eliminated because of the small sample size) were used to validate the age structure of *O. stewartii*. There were 16 age classes for females and 9 for males.

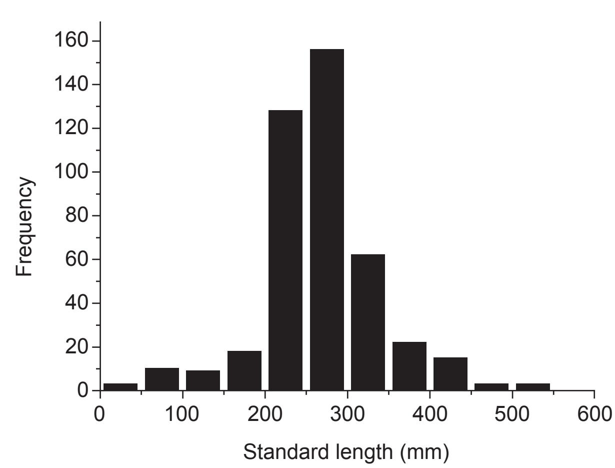

Fig. 2. Length frequency distribution of specimens.

The 3-5 yr age groups accounted for 86.08% of the total sample. The age composition is shown in figure 3.

Length-weight relationship

The length-weight relationships were calculated for each individual sex first. Body weight exponentially increased with *SL* (mm) by the following relationships:

$W = 0.767 \times 10^{-5}\ SL^{3.098}$ ($r^2 = 0.990$) for males and

$W = 1.33 \times 10^{-5}\ SL^{2.997}$ ($r^2 = 0.971$) for females.

The relation between *SL* and *W* was best described by a power function. Individual length

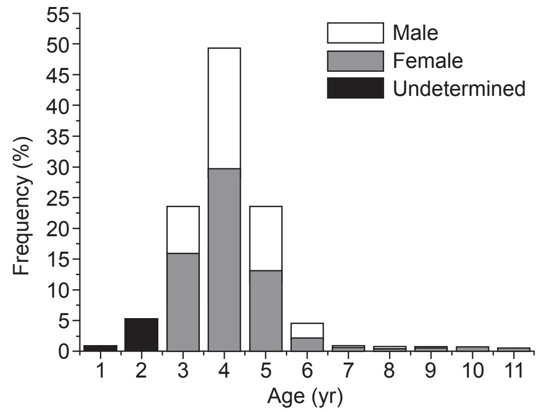

Fig. 3. Age structure of *Oxygymnocypris stewartii*.

Table 1. Sample size (*n*), mean and range of standard length (*SL*; mm), and body weight (*W*; g) at age of *Oxygymnocypris stewartii* (sex of individuals that were < 2 yr old was not identified)

	Females				
Age (yr)	Mean of *SL* ± S.D.	Range of *SL*	Mean of *W* ± S.D.	Range of *W*	*n*
1	46.8 ± 1.230	46.0-47.7	0.85 ± 0.212	0.7-1	2
2	100.3 ± 14.88	77.8-134.1	12.7 ± 8.472	5.6-33.3	18
3	220.8 ± 28.05	117.0-259.0	153.7 ± 45.40	38.9-232	40
4	273.6 ± 29.24	221.0-360.0	283.2 ± 96.51	125.0-611.0	73
5	317.8 ± 43.28	237.0-395.0	464.5 ± 178.5	194.0-818.0	24
6	390.4 ± 27.09	330.0-417.0	726.6 ± 154.7	435.0-943.0	8
7	391.5 ± 9.192	385.0-398.0	798.5 ± 116.7	716.0-881.0	2
8	371.0 ± 43.84	340.0-402.0	607.0 ± 210.7	458.0-756.0	2
9	451.5 ± 49.03	407.0-502.0	1226.5 ± 332.2	835.0-1519.0	4
10	394.0 ± 37.64	361.0-435.0	674.7 ± 137.4	525.0-795.0	3
11	395.0	395.0	725.0	725.0	1
12	443.0	443.0	1047.0	1047.0	1
14	546.0	546.0	1976.0	1976.0	1
15	540.0	540.0	2502.0	2502.0	1
17	440.0	440.0	958.0	958.0	1
20	451.0	451.0	1028.0	1028.0	1

	Males				
Age (yr)	Mean of *SL* ± S.D.	Range of *SL*	Mean of *W* ± S.D.	Range of *W*	*n*
1					
2					
3	209.2 ± 33.87	103.7-243	139.8 ± 61.46	14.2-258	19
4	275.7 ± 30.38	210-343	296.8 ± 102.8	152.0-589.0	48
5	301.4 ± 32.59	241.0-367.0	392.7 ± 145.2	173.0-697.0	16
6	358.2 ± 42.48	304.0-411.0	598.2 ± 228.9	356.0-928.0	5
7	416.0	416.0	800.0	800.0	1
8	408.0 ± 46.67	375.0-441.0	809.5 ± 277.9	613.0-1006.0	2
9	425.0	425.0	853.0	853.0	1
10					
11					
12					
14					
15					
17					
20					

and weight relationships were not found to significantly vary between the sexes (ANCONA $F = 0.018$, $p = 0.892$), so the data were pooled, and a new relationship was established. The relationship was as follows: $W = 1.30 \times 10^{-5}\ SL^{3.002}$ ($r^2 = 0.970$) (Fig. 4).

Growth models

The VBGFs were first fitted to each sex separately. Individuals the ages of which were < 3 yr were fitted to both sexes' functions. The age composition of *O. stewartii* was complicated, which may have caused a great impact on the results of the VBGF when a small sample size group was used. Sample sizes beyond the age of 6 yr were negligibly small as there were 1, 2, and 1 male individuals and 2, 2, and 4 female individuals at the ages of 7, 8, and 9 yr, respectively. There was only a single female each for the ages of 11, 12, 14, 15, and 20 yr. So the VBGF was fitted using data groups which only included age groups 1 to 6 yr.

The VBGFs fitting the length-at-age data were as follows (Fig. 5):

$L_t = 599.3939\ [1 - e^{-0.1686(t - 0.6171)}]$ ($r^2 = 0.9841$) for males and

$L_t = 877.4821\ [1 - e^{-0.1069\ (t - 0.5728)}]$ ($r^2 = 0.9855$) for females.

The ARSS results indicated that the growth curves did not significantly differ for the 2 sexes ($F = 1.51$, $p = 0.25$).

The VBGFs fitting the weight-at-age data were as follows:

$W_t = 3091.3496\ [1 - e^{-0.1686(t - 0.6171)}]^{3.098}$ for males and

$W_t = 8805.1493\ [1 - e^{-0.1069\ (t - 0.5728)}]^{2.997}$ for females.

Growth rate and growth inflection

The growth performance indexes (φ) for the both sexes were φ = 4.9153 for females and φ = 4.7823 for males.

The instantaneous growth rate of *O. stewartii* from ages 1 to 2 yr was estimated to be 2.70 for both sexes, and was 2.49 for females are 2.40 for males from ages 2 to 3 yr. These values were far higher than those of *Gymnocypris selincuoensis* and *G. przewalskii przewalskii* (Chen et al. 2002a, Zhao et al. 1975). However, after that, the growth rate decreased and became lower than those of the other 2 species (Fig. 6).

The growth inflexions of the 2 sexes were

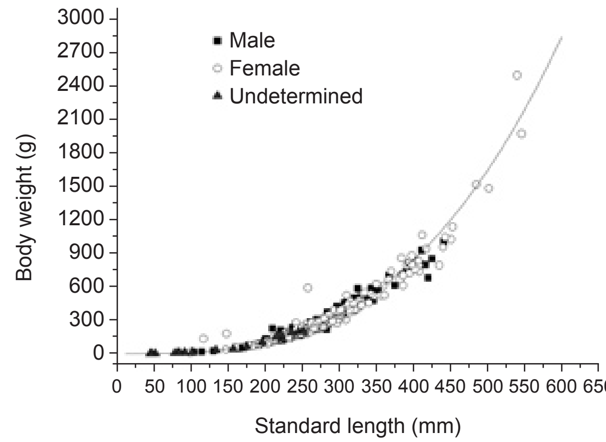

Fig. 4. Relationship between the body weight and standard length of *Oxygymnocypris stewartii*.

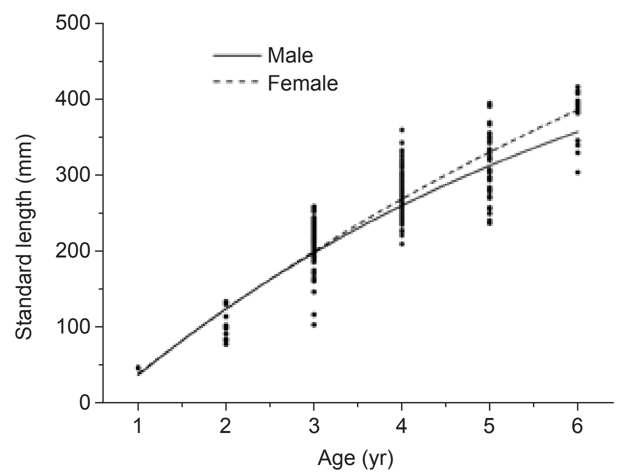

Fig. 5. Von Bertalanffy growth function curve fitted to the length-at-age data of *Oxygymnocypris stewartii*.

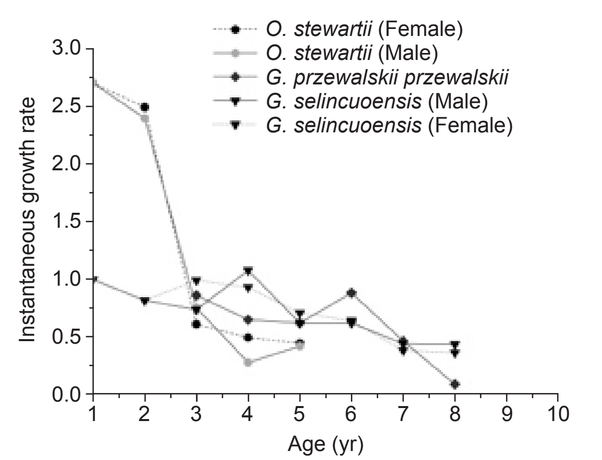

Fig. 6. Instantaneous growth rates of 3 different populations of *G. selincuoensis*, *G. przewalskii przewalskii*, and *O. stewartii* in Tibet.

t_i = 3.91 for females and t_i = 3.53 for males.

DISCUSSION

Growth performance

The growth of fishes can be affected by many factors such as sex, maturation level, food limitations, changes in behavior, and environmental conditions (Beamish and McFarlane 1983); the growth of *O. stewartii* was also affected by these variables. Its growth was relatively higher than other schizothoracines such as *G. cuoensis*, *G. selincuoensis*, *Ptychobarbus dipogon*, and *Schizopygopsis younghusbandi younghusbandi* which inhabit the same elevations and region (Chen et al. 2002a 2009, Yang et al. 2002, Li and Chen 2009). The growth performance index of *O. stewartii* (φ = 4.7823) was higher than those of *G. cuoensis* (φ = 4.0759) (Yang et al. 2002), *G. selincuoensis* (φ = 4.2140) (Chen et al. 2002a), *P. dipogon* (♀: φ = 4.5076; ♂: φ = 4.4659) (Li and Chen 2009), and *S. younghusbandi younghusbandi* (φ = 4.2657) (Chen et al. 2009). These growth differences might be related to feeding. Animal food has more energy than other foods (Hofer et al. 1985). *Oxygymnocypris stewartii* is piscivorous, and its food would have more energy than that of the other schizothoracines referred to above. (2) *Oxygymnocypris stewartii* showed relatively lower growth performance than other piscivorous cyprinid fishes such as *Culter alburnus* Basilewsky of Wu (φ = 5.2953) (Hu et al. 2000) and Cheng Lakes (φ = 6.8840) (Ling et al. 2006). These growth differences might have resulted from environmental factors, and the most likely one is temperature. Low temperatures can reduce the growth rate of ectotherms (Yamahira and Conover 2002, Angilletta et al. 2004). It was reported that fish are very sensitive to temperature changes and respond to a change of even 0.03°C (Bull 1952). Elliott (1994) also reported that the energy budget of fish depends on the water temperature, size, and level of energy intake. Temperature, in particular, has a marked effect on both the maximum and maintenance energy intakes of fish. The annual average water temperatures in Yarlung Tsangpo River, Wu Lake, and Cheng Lake are 6-11 (Liu 1999), 18.7, and 17.7°C (Wang and Dou 1998), respectively. Metabolic rates in cold environments are slower, so the growth performance of *O. stewartii* was relatively lower than the other piscivores belonging to the same family and inhabiting relatively warmer environments.

Commercial fishing conditions and management implications

Based on our and other studies as well as some field surveys (Wu and Wu 1992, Yue and Chen 1998, Chen et al. 2009, Li and Chen 2009), fishing has led to sharp reductions in the abundances of fishes in Yarlung Tsangpo River, and the current fishing pressure is still high in this river. For example, there were more than 20 boats around Lhasa engaged in commercial fishing every day. Presently, *O. stewartii* is rare in the catches, and most samples caught in catches and sold in the markets are immature, being aged 3-5 yr. Both of these facts indicate that the existing commercial fishing is not sustainable, and will destroy the population of *O. stewartii*. Moreover, *O. stewartii*'s life history strategy is likely to be *K*-selected characteristics, which means that it would be difficult to restore the population once it was destroyed. Therefore, special attention should be paid to *O. stewartii*, which may possess no means of compensating for reductions in its population. We suggest that some regulations be promulgated as soon as possible. The government should publish a law to forbid fishermen from capturing *O. stewartii*. Further scientific investigations focusing on the population dynamics of this valuable species are required in the near future.

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